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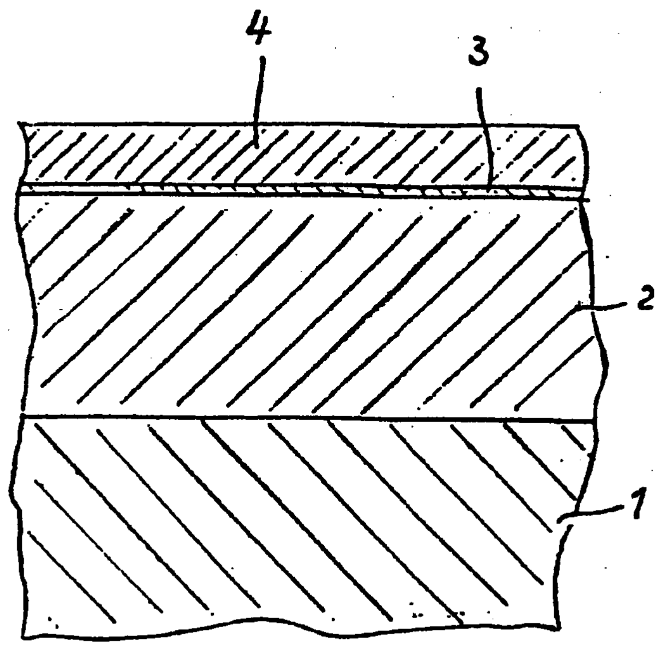
(54) **A composite bearing comprising several materials**

(57) The invention relates to a composite plain bearing of several materials, comprising a steel support bush (1), a layer (2) of low-friction metal consisting of an aluminium-tin bearing metal with a tin content in the range of from 6 to 40% and a bearing layer (4) of a lead-based or tin-based alloy, wherein an adhesion-imparting layer (3) of electrochemically deposited iron having a hardness in the range of from 120 to 200 Vickers units is disposed between the low-friction metal (2) and the bearing layer (4). There is also provided a method for the production of this composite plain bearing of several materials.



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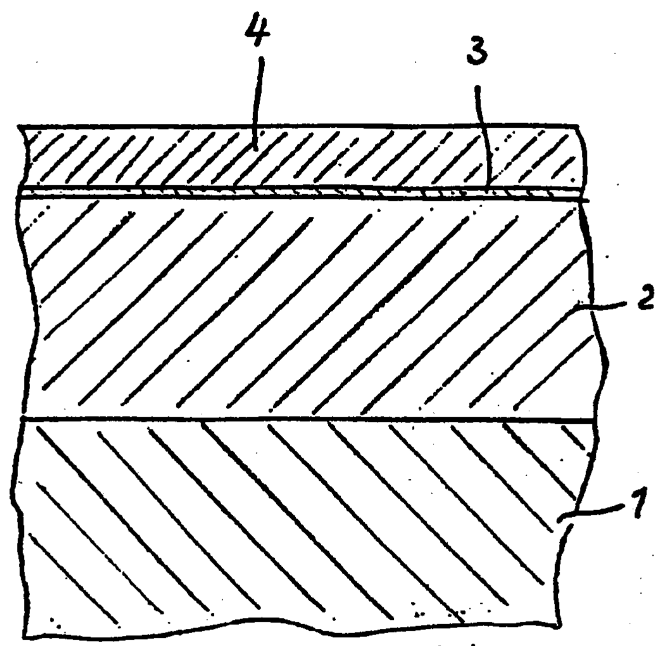

SPECIFICATION

A composite plain bearing comprising sev ral materials

The present invention relates to composite plain bearings.

Bearing bushes or shells constitute one of the most important material embodiments of composite plain bearings and comprise a steel support bush and a layer of low-friction metal consisting of aluminium-tin allow, the tin content of which is in the range of from 6 to 40%.

In most cases it is necessary for the running surface of the bearing to be provided with an additional layer, usually applied electrochemically, and 20 to 40 µm thick, consisting of an alloy which is of substantially lower hardness than the aluminium-tin alloy. Accordingly, the aluminium-tin low-friction metal is able to conform to the shape of the steel shaft during the wearing-in or running-in stage only to a very limited extent. The conformation process essentially comprises a plastic deformation and also partial wear of the bearing layer. Aluminium-tin alloys, in particular those with tin contents in the range of from 6 to 20%, scarcely deform plastically to the shape of the shaft, whilst in the areas of the bearing surface under uneven friction conditions caused by geometrical imperfections in the bearing bush and shaft they do not wear while simultaneously smoothing the running surface, instead roughening occurs in the heavily loaded areas and, under unfavourable conditions, even scoring may occur. These variations in the running surface have a detrimental effect on the formation of a lubricant film of uniform thickness and local uneven friction, which should be restricted to the wearing-in stage, persists so that considerable bearing damage can occur even after relatively brief operating times.

To improve the conformation behaviour of a bearing by providing a further electrochemically applied layer, in a known bearing of this type it was necessary to solve the problem posed by the electrochemical depositon of lead and tin-based alloys on to aluminium-tin low-friction metal. In view of the extremely strong tendency of aluminium towards passivity, it is not possible to effect direct deposition on to the aluminium-tin surface. To provide the high adhesion strength required by the electrochemical layer, firstly it is necessary to apply a cementation deposit of zinc, by electroless deposition from an alkaline bath, on to the aluminium-tin and then by electrochmical deposition thereon an approximately 5 µm thick nickel layer. This nickel layer then constitutes the adhesion base for the 30 to 60 µm bearing layer of lead-tin, lead-tin-copper or tin-antimony.

Therefore, in steel bearings with an electrochemically applied aluminium-tin layer the nickel has a simpler task than in steel bearings with an electroch mically applied lead-bronze layer, wh r in the so-called nickel barrier, in additi n to ensuring good adhesion of the bearing layer, also constitues a diffusion barrier between the copper of the lead bronze and the tin of the electrochemically applied layer, thereby preventing the formation of brittl interm tallic copper-tin phases.

In the known bearing, nickel has proven over a long period to be a satisfactory adh sion base on aluminium-tin when working with surface-hardened shaft journals, as is the case in small engines. In such cases it is relatively harmless if, after substantial operating periods, the soft electrochemically applied layer wears locally, exposing the nickel layer, and the shaft comes into contact with the nickel. However, the conditions are different in large diesel engines with soft journals.

The electrochemically deposited nickel in the known bearing has a hardness of about 320 HV, which is thus higher than the surface hardness of shafts which have not been surface-hardened. If the electrochemically applied layer wears to such an extent that the shaft journal reaches the nickel adhesion base, two almost equally hard materials are in mutual contact, moreover, the materials are very similar metallurgically. This unfavourable contact pairing leads to wear in the shaft journal which, initially, is noticeable as roughening but, finally in an advanced stage, appears as scoring.

Since the nickel layer has the considerable thickness of 5 µm, it cannot be assumed that the shaft will remain in contact with the nickel layer for only a relatively brief period and will then reach the low-friction aluminium-tin layer, whereby no further danger would arise, the running-in process having ended and a uniform contact reflection having been formed in the bearing. On the contrary, because of the thickness of the nickel layer, with continued wear of the electrochemically applied lead-tin-copper bearing layer the surfaces of the exposed adhesion base spread and, finally, the shaft runs extensively on nickel. At this stage the shaft is at considerable risk.

It has to be taken into account that because of increasing heavy-oil operation even in four-stroke diesel engines and because of the contamination of the lubicating oil with chemically corrosive substances causes thereby, as well as with soot and metal oxide particles having an erosive action, ther is an increased danger of relatively rapid wear of the lead-tin-copper bearing layer. Practical tests have thus shown, under favourable conditions, that the nickel barrier is exposed even after a few thousand hours operation and that a distinct roughening of the shaft has occurred.

In addition to its undesirably high degree of hardness, the nickel layer of the known bearing also exhibits very disadvantageous behaviour in other respects. At the operating temperatures prevailing in the bearing, which can rise as high as 140°C, in the course of several thousand operating hours the intermetallic phases Ni_3Sn and Ni_3Sn_2 are formed b tween nickel and tin which, compared with the pure nickel layer, have the substantially higher hardness of 500 to 600 HV. This intermetallic connecting layer can build up to a thickness of several micrometres. For example, on the big-end bearing of a diesel engine operated at medium speed an intermetallic layer of 3 µm thickness has been found between the nickel barrier and the lead-

tin-copper bearing layer after 18,000 operating hours. The increas in thickness f this lay r continu s at an approximately constant rate.

If the w aring of th lead-tin-copp r bearing layer takes place relatively rapidly, only a small amount of intermetallic phase is formed when the nickel barrier is reached. However, if wear takes place slowly, the shaft comes into contact with an intermetallic layer which in the meantime has built up to a thickness of several micrometers and which then causes substantial abrasion of the shaft.

Because of the gradual build up of the intermetallic connecting layer, remounting of the known bearing having an electrochemically applied aluminium layer with a nickel barrier also involves considerable risk; namely, if for any reason a bearing is demounted after a relatively long operating period, for example after 15,000 operating hours, and the electrochemically applied layer is still present on all the bearing surface, i.e. the nickel barrier has not yet been exposed, the bearing will as a rule be remounted on the assumption that it will be able to conform once more to the shaft. Since a very hard intermetallic layer has formed on the nickel barrier after such a long operating period, it has to be taken into consideration that, after passing through the existing remainder of the lead-in-tin-copper bearing layer, the shaft will reach the intermetallic phase and because of the substantial layer thickness of the latter it will be exposed to an intensified abrasion effect over a relatively long period.

In addition to the considerable wearing action, the formation of the intermetallic nickel-tin layer has a further disadvantage. The tin content of the intermetallic layer of Ni_3Sn and Ni_3Sn_2 is approximately 50% by weight of tin. The tin in the intermetallic layer originates in the lead-tin-copper layer and as a result the tin content of the lead-tin-copper layer is depleted. If one starts from an original 30 μm thick lead-tin-copper layer with 10% tin, which has been worn down to a mean layer thickness of 15 μm, an intermetallic nickel-tin-layer of 2 μm will have been formed simultaneously, this means that the tin content of the lead-tin-copper layer has dropped on average by 2%. At heavily worn locations this tin depletion may be substantially higher.

However, as the tin content decreases both the corrosion resistance and hardness of the electrochemically applied bearing layer are reduced. This impairment of the bearing layer properties is particuarly noticeable in heavy-oil operation with its corrosive and particle-rich abrasive combustion products.

The numerous disadvantages of the nickel barrier in known aluminium-tin bearings have induced well known manufactures of large dies l engines, in the abs nce f an adhesion base other than nick l, t dispense with th lead-tin-c pper b aring lay r altogether and to allow th shaft to run directly on aluminium-tin. The risks undoubtedly ntailed thereby are considered to be less than the dangers arising from the nickel barri r.

Th problems which aris for th nickel barrier n aluminium-tin are basically also present in steel bearings with an lectrochemically appli d lead-bronz layer, wher in the nickel is used as a diffusion barrier layer. However, since a barrier layer of 2 to 3 μm is sufficient in those bearings, the danger arising from the pure nickel layer is less than in the doubly thick nickel layer of the aluminium-tin bearing.

For bearings with an electrochemically applied lead-bronze layer, it is to be noted that as a diffusion barrier nickel does in fact prevent the formation of the extremely harmful Cu_6Sn_5 phase but by itself with tin it also exhibits a reaction which does not stop at bearing operating temperatures.

Hitherto these drawbacks of nickel as an adhesion base of lead-tin-copper has be taken into account, since the nickel barrier could not be replaced with another metal.

It would be desirable to provide an improved composite plain bearing of the type described at the beginning, which not only obviates the above-described disadvantages but meets the prerequisites therefor, namely that with continuing wear of the soft electrochemically applied bearing running layer the smooth and soft shaft surface can pass through the adhesion layer without any damage so that, finally, it runs on the low-friction metal layer under long-lasting and satisfactory hydrodynamic plain bearing conditions.

Accordingly the present invention provides a composite plain bearing of several materials, comprising a steel support bush and a layer of low-frction metal consisting of an aluminium-tin bearing metal with a tin content in the range of from 6 to 40% and a bearing layer of a lead-based or tin-based alloy, wherein an adhesion-imparting layer of electrochemically deposited iron having a hardness in the range of from 120 to 200 Vickers units, preferably of from 120 to 150 Vickers units, is disposed between the low-friction metal and the bearing layer.

In a preferred embodiment of this invention the electrochemically deposited iron layer has a thickness of only about 1 to 3 μm, a mean layer thickness of 2 μm being preferred.

One advantage of an iron adhesion base over a nickel adhesion base is its lower hardness value and lower layer thickness. The bearing according to the invention also has the advantage that the lower hardness value attained by heat treatment has the result that the iron layer is substantially free of so-called effusible hydrogen, i.e. hydrogen able to escape from the metal, whereas a nickel layer, on to which the bearing layer has to be immediately deposited electrochemically, still contains all the absorbed hydrogen. Preferably the iron layer contains no hydrogen which can be driven off by heating to a temp rature of up to 250°C. Th refore, b arings with an iron adhesion bas exhibit no blistering in the lectrochemically deposited bearing layer. In this context it is pointed out that in bearings with a nickel adhesion base the bearing layer is p rf rated by a plurality of small bubbles which results from th hydrogen formed during l ctrochemical applicati n f the nickel adhesion

bas . The load-bearing capacity of the bearing layer will be reduced if the hydrogen escapes only wh n the b aring is put to use in an engine. This drawback is thus obviated in the bearing according to the invention. This significant difference between the bearing according to the invention and a bearing with a nickel adhesion base can be rendered readily apparent if the bearings in question are heated to 140°C for two to three hours, after deposition of the bearing layer.

In order to assure the desired lower hardness value of the iron adhesion base, it is necessary for the crystal structure of the electrochemically deposited iron layer following treatment to have a reduced dislocation density in relation to the conditions immediately after electrochemical deposition. The manner in which this lower hardness value is attained will be explained hereinafter.

It is known that iron represents a satisfactory diffusion barrier between copper and tin and has thus also been proposed as a diffusion barrier on lead bronze (British patent application 8612594). Remarkably, it has now been demonstrated that iron can also be used as an adhesion base for electrochemically applied layers on aluminium-tin bearing metal; this was not known hiterto. Apropriate research could not be carried out hitherto in the laboratory because there had been no success in depositing adherent iron layers on to aluminium-tin bearing metal.

Surprisingly, success has been achieved in developing an electrochemical method in which the iron layer is treated in such a way, without impairing its adhesion-imparting properties, that it attains the softness of chemically pure iron and even with a thickness of only 2 µm constitutes a completely closed layer.

Accordingly the present invention also provides a process for producing a composite plain bearing comprising, prior to the deposition of the iron layer, the electroless deposition from a zinc bath of a layer of zinc onto the tin-aluminium bearing metal, partly redissolving the zinc, electrochemically depositing the iron and subjecting the iron layer to heat treatment.

According to a preferred embodiment, 20 to 40% of the deposited zinc layer is redissolved.

It is preferable for the deposition of the iron layer to take place in an iron chloride bath. The deposition temperature should preferably be in the range of from 85 to 110°C, more preferably from 95 to 105°C.

The deposition of iron to the aluminium-zinc surface from a strongly acid chloride bath at a temperature in the range of from 95 to 105°C takes place after a previous cementation treatment in a sodium zincate solution. The high temperature is necessary so as to provide an iron layer with as little as possible inherent mechanical stress and of uniform layer thickness. The duraction of the zincat pickling treatment must b so calculat d that a part of th zinc layer can be redissolved chemically in a hot iron chloride bath, before deposition of iron begins. An iron layer with a high degree of adhesion strength is obtain d only if this rule is observed.

After the deposition of iron, the electrochemical process is interrupted and the iron-coated bearing bushes undergo a heat treatment preferably at a temperature of from 250 t 300°C, more preferably at about 280°C. In the course of such a heat treatment lasting three hours the hardness of the iron layer drops from 300 to 350 to from 125 to 135 Vickers units.

It is not necessary for this heat treatment to be carried out in an inert atmosphere and heating can take place with air admission. An initial blue oxide layer is then formed on the iron surface. The electrochemical process is then continued with this initial layer. The iron surface is pickled by brief immersion in dilute hydrochloric acid and is activated for the deposition of the electrochemically applied bearing layer. The remaining layer of iron is in the range of 1.5 to 2.5 micrometres thick. It is now possible for the electrochemical bearing layer to be deposited in the same manner as on a nickel adhesion imparting layer.

As an alternative to lead-based bearing layers, tin-based bearing layers can be applied, e.g. ternary layers with 7% antimony and 1% copper. A nickel adhesivion base is much more disadvantageous in these bearing layers with a high tin content than in lead-based alloys, because the formation of the intermetallic nickel-tin phases takes place much more rapidly.

EXAMPLE

A composite bearing with an outer diameter of 250 mm and a wall thickness of 10 mm is subjected to the pretreatment conventionally used also for known bearings having a nickel layer, namely treatment for 30 seconds in a 20% sodium zincate pickle, rinsing with water and maintanance without current for 10 seconds in an iron chloride bath with a pH value of 1 and at a temperature of 95°C. Iron is then deposited for a period of 1.5 minutes at a current density of 1.5 A/cm^2. Subsequently, heat treatment is carried out for 3 hours at 280°C.

The drawing shows on a greatly enlarged scale the structure of a multilayer plain bearing according to the invention in a flat embodiment. Here 1 designates the steel support bush on to which a bearing metal 2, comprising a mixture of aluminium and tin, it rolled generally under high pressure. In the bonding zone between the bearing metal 2 and the bearing layer 4 there is provided an electrochemically applied adhesion base 3 of iron having an extremely small layer thickness in relation to the other layers.

Of course, the adhesion base according to the invention and the associated method of applying it on to the bearing metal may also be used in those bearing which do not have a flat machined bearing metal surface, for example in bearings with a matrix-like or grooved surface.

CLAIMS

1. A composite plain bearing of several mat rials, comprising a steel supp rt bush and a layer of low-friction metal consisting of an aluminium-tin bearing metal with a tin cont nt in the range f from

6 to 40% and a bearing layer of lead-based or tin-based alloy, wherein an adhesion-imparting layer of electrochemically deposited iron having a hardness in the range of from 120 to 200 Vickeers units is disposed between the low-friction metal and the bearing layer.

2. A composite plain bearing as claimed in Claim 1, wherein the iron layer has a hardness in the range of from 120 to 150 Vickers units.

3. A composite plain bearing as claimed in Claim 1 or 2, wherein the electrochemically deposited iron layer has a thickness in the range of from 1 to 3 μm, preferably 2 μm.

4. A composite plain bearing as claimed in any one of Claims 1 to 3, wherein the electrochemically deposited iron layer contains no hydrogen which can be driven off by heating to a temperature of up to 250°C.

5. A composite plain bearing as claimed in any one of Claims 1 to 4, wherein the crystal structure of the electrochemically deposited iron layer has a reduced dislocation density following further treatment in relation to the condition after electrochemical deposition.

6. A method of producing a composite plain bearing as claimed in any one of the preceding claims comprising, prior to the deposition of the iron layer, the electroless deposition from a zinc bath of a layer of zinc onto the tin-aluminium bearing metal, partly redissolving the zinc, electrochemically depositing iron and subjecting the iron layer to heat treatment.

7. A method as claimed in Claim 6, wherein from 20 to 40% of the deposited zinc layer is redissolved.

8. A method as claimed in Claim 6 or 7 wherein the iron layer is deposited from an iron chloride bath.

9. A method as claimed in Claim 8, wherein the deposition temperature in the iron chloride bath is in the range of from 85 to 110°C, preferably from 95°C to 105°C.

10. A method as claimed in any one of Claims 6 to 9, wherein the heat treatment of the iron layer is carried out at a temperature in the range of from 250°C to 300°C, preferably at about 280°C.

11. A bearing as claimed in Claim 1 substantially as hereinbefore described.

12. A method as claimed in Claim 1 substantially as hereinbefore described with reference to the example.

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